NRTC Project

National Rotorcraft Technology Center

UPN 712 - 50

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Objectives

- **Briefly describe NRTC collaboration and technology focus areas (for the benefit of potential new government participants)**
- **Provide synoptic view of knowledge product from 6 years of NRTC/RITA collaboration**

Project Overview

Rotorcraft Program
National Rotorcraft Technology Center

Project Goal

- Ensure NASA and DoD access to high TRL rotorcraft technology to meet the needs of the national air transportation system and the national defense.

Technical Objectives

- Implement **design tools** in the domestic rotorcraft industry that will provide faster, higher quality, and more reliable designs for civil and DoD missions
- Implement **integrated design and manufacturing** technology in the production of new rotorcraft to improve performance, quality, and safety.
- Implement high TRL **noise reduction** technology to reduce noise levels in the cabin and the noise footprint in the community.
- Develop and implement rotorcraft operational and certification procedures, and subsystems to improve **aviation safety**.

Project Overview (cont.)

Approach

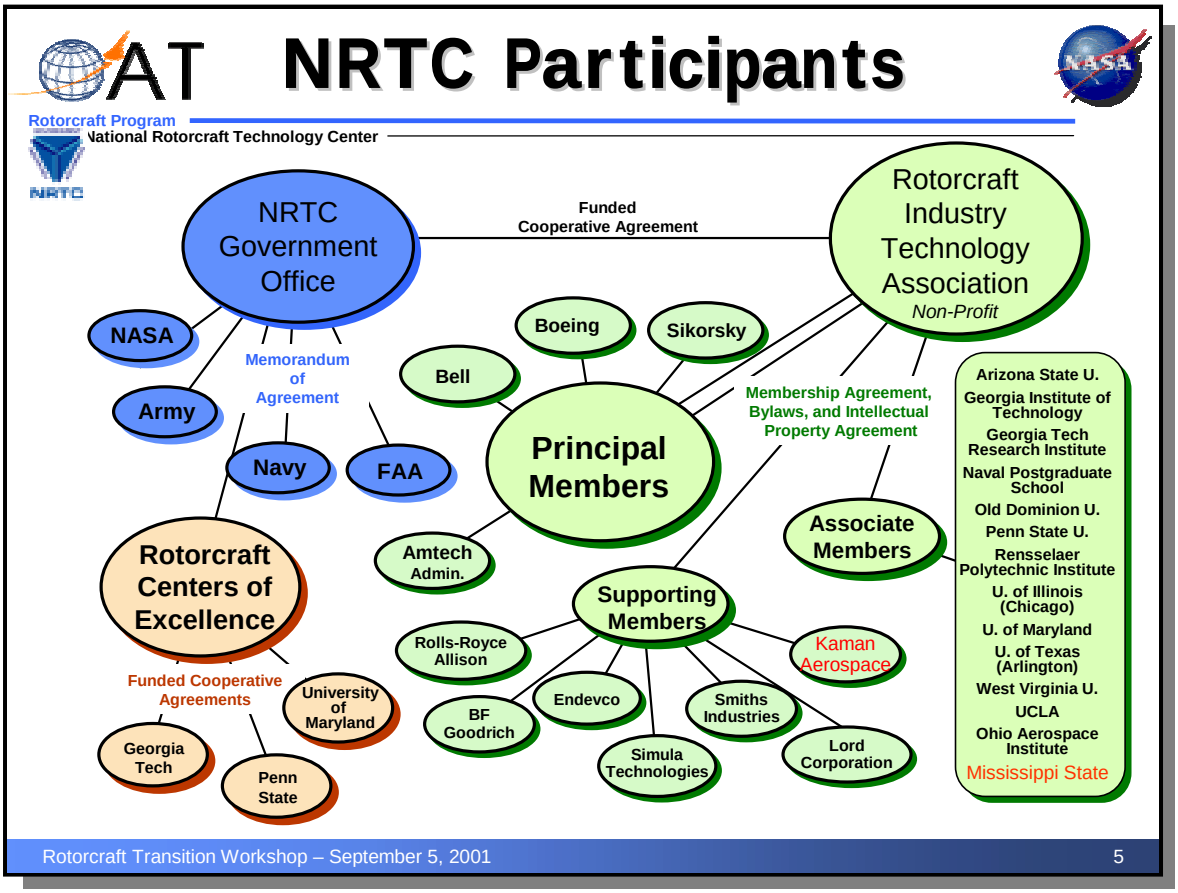
- "Pre-competetive" technical agenda proposed by Industry, with Government advisory review
- 50/50 Cost sharing between Government and Industry
- Sharing of results within Rotorcraft Industry Technical Association (RITA) and Government. (Intellectual Property belongs to RITA)

Benefit

- A globally competitive U.S. rotorcraft industry augmented by Government laboratory and University developed technology

Partners

- National Rotorcraft Technology Center (U.S. Army, U.S. Navy, FAA)
- Rotorcraft Industry Technical Association (Bell, Boeing, Sikorsky, RITA Academic and Supporting members)



Collaboration is a key element in the success of the National Rotorcraft Technology Center. The center is a partnership of government, industry, and academia. Participating government agencies include NASA, the Army, the Navy, and the FAA. NASA is the hosting agency, providing a venue for the government office at Ames Research Center and administrative support for program management. The Army provides significant funding and staff support to interface with other research programs within AFDD and AATD. The Navy and FAA also provide staff support to interface with complementary programs at NAVAIR and the FAA Tech Center. Roles and responsibilities among the government participants are defined within several Memoranda of Understanding. A funded cooperative agreement, developed under the guidelines of the NASA Grants Handbook defines the functional and funding relationships between the government and the rotorcraft industry technology association (RITA). RITA is a non-profit corporation comprised of three principal rotorcraft manufacturers (Bell Textron, Boeing Helicopters, and Sikorsky Aircraft), several supporting members companies who supply components and subsystems to the aircraft industry, and about a dozen associate university members who have a strong research focus in the technology base supporting rotary wing aircraft. Roles and responsibilities among RITA members are defined in the RITA bylaws and operating procedure documents. The NRTC government office also manages a Rotorcraft Centers of Excellence (RCOE) program led by the Army and supported by NASA. This program funds basic research in rotorcraft-related disciplines through cooperative agreements with three academic centers.

Technical Program

Rotorcraft Program
National Rotorcraft Technology Center

80 to 100 projects per year

RITA WBS:

- Aeromechanics, Handling Qualities, and Acoustics
- Structures and materials
- Composites Development
- Design, Manufacturing Technologies and Integration
- Manufacturing Technologies
- Crewstations, Avionics, and HUMS
- Subsystems Technologies
- Operations and Certifications

NASA WBS:

- Noise Reduction
- Aviation Safety
- Design Tools
- Integrated design and Manufacture

RITA proposes a comprehensive technical program each year comprised of up to 100 individual projects organized according to a work breakout structure that is effective in the context of the industry's requirements. The program is reviewed by the NRTC government office, with feedback to RITA that aims to leverage government assets and knowledge base, and maximize the effectiveness of each project. Each participating government agency may choose to organize the annual technical program according to a WBS that is aligned with agency goals and objectives.

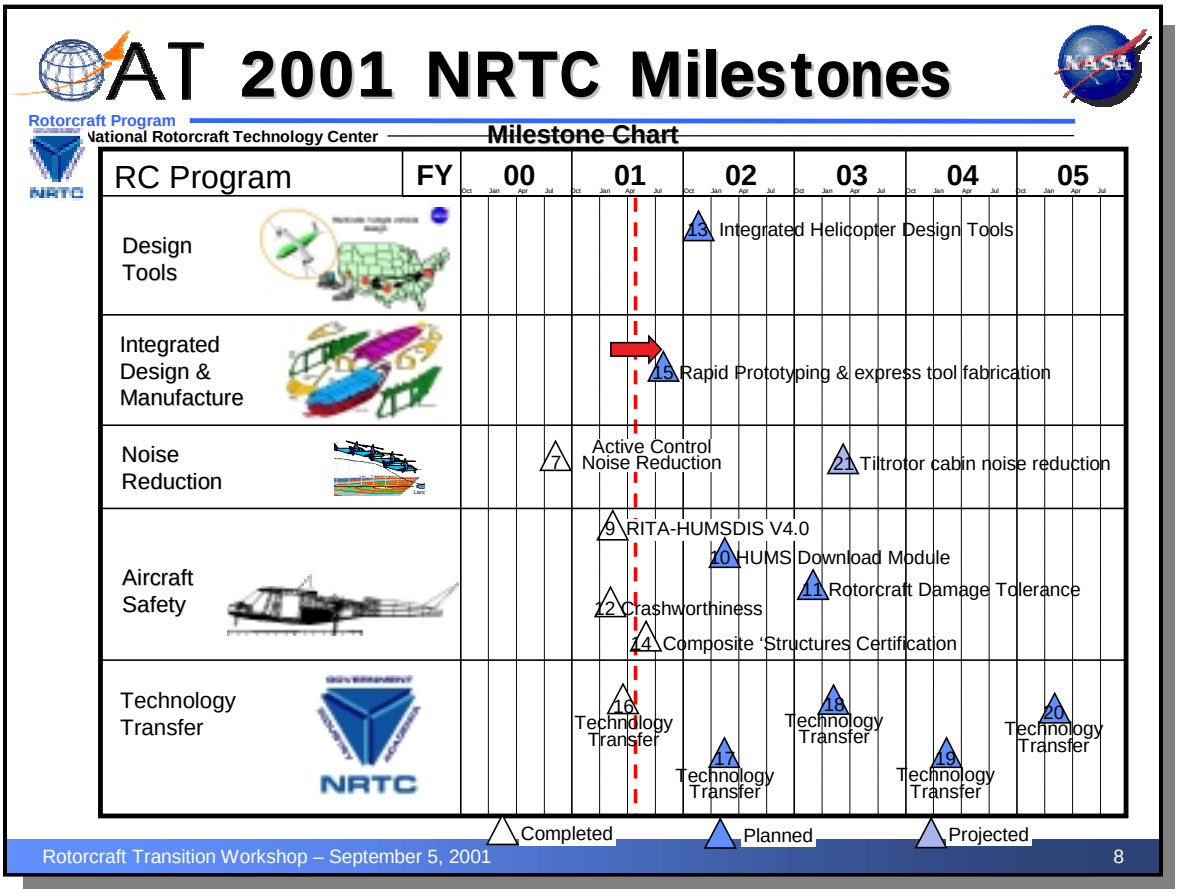
Project Accomplishments

NASA Milestones

Transition to Products

Literature

- Annual reports
- Final Reports
- Publications



Milestones that typically identify technology transition to product are defined collaboratively with RITA. Technical milestones are typically chosen in areas of broad RITA teaming, often at the conclusion of a multi-year sequence of RITA projects (subtasks in NASA NRTC project nomenclature). Technical milestones are reported as tasks within the NASA Rotorcraft Program management system. The primary objective of the NRTC project is technology transfer, both within participating RITA companies and with the government. An single project level annual milestone addressing this objective is the RITA year end review.

Technical Accomplishments

Rotorcraft Program
National Rotorcraft Technology Center

Rotorcraft Crashworthiness

M. Smith (Bell), A. Bolukbasi (Boeing), C. Clarke (Sikorsky), L. Labun (Simula)
January 2001

GPRA Milestone Completed

Relevant Milestone: Demonstrate strong correlation of analytic model predictions with full-scale existing and new water/soft-soil-impact test results. (NRTC #12, January, 2001)

Shown:, Actual fuselage damage from full scale crash test compared with prediction of crash damage to UH-1H fuselage for soft soil crash conditions.

Accomplishment / Relation to Milestone and ETO:

- Finite element modeling has been used to characterize the airframe, aircraft skins, impact media (water and soil), and contact surface. A simulation of the crash tests in both soft soil and water have been computed, along with resulting accelerations and damage to the rotorcraft structure. Crash tests in both water and soft soil have been performed with full scale hardware. Test results have validated the models.
- Cabin and seat G-forces for water and soft soil crashes are more severe than hard surface crashes because landing gear are not as effective. This modeling and test effort has identified the need for a revised standard for energy absorption in seats and floor structures. These results will lead to much better crash survivability for rotorcraft passengers and crew, contributing to the safety enterprise technology objective. This research received the American Helicopter Society 2001 Harry T. Jensen Award for an outstanding contribution to improved helicopter safety.

Future Plans: This analytical capability will be used to design safer rotorcraft. The analysis will be extended to include the special structural requirements of large rotorcraft. The industry will develop a new generation of energy absorbing metal and composite structures in the landing gear, floor and seats.

ETO: Safety

This is an example of the way technical milestones are reported to NASA management. These 2-page summaries are available for all Project milestones.

Technical Accomplishments

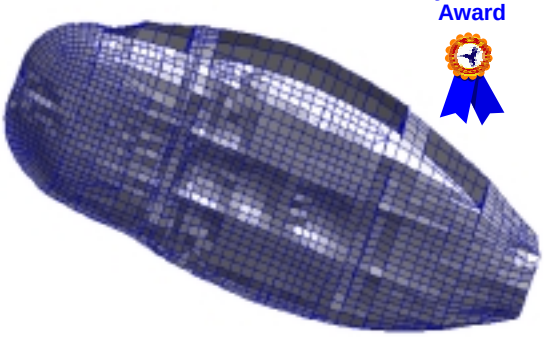
Rotorcraft Program
National Rotorcraft Technology Center

Finite element models can accurately predict crash damage

GPRA Milestone Completed

AHS 2001
Harry T. Jensen Award

Actual full scale crash test specimen, showing damage to aircraft skins and airframe structure



Finite element model of UH-1H helicopter floor and bottom surface structure after crash onto soft soil

A descriptive graphic is included with each “2-pager”

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

- **This new aircraft will be an important component of the national air transportation system, serving as a short-haul, people-moving workhorse**
- **S-92 provides H-60 fleet with the potential upgrades of a more capable dynamic system and larger cabin**
- **NRTC/RITA contributions for S-92 design and/or certification include:**

Sikorsky S-92

- Noise and vibration reduction systems: 1) Passive (isolation/optimal sound treatment) for cabin noise, 2) optimal active-vibration reduction
- SATNAV Precision Approach for terminal area operations and noise reduction
- Enhanced Ground Proximity Warning System
- Electromagnetic interference protection
- Rotor flaw-tolerant certification …… with damage-tolerance data
- Rotor design ……. utilizing composite-material, structural fatigue-test data
- Tail-rotor flex-beam certification ……. with energy-release-rate methodology
- Crashworthy structures, fuel tanks and flotation systems
- Bird-strike resistance ….. certified with analysis versus extensive testing
- Advanced rotor-ice-protection system
- Titanium high-speed machining

At the end of the first 5-year NRTC-RITA funded cooperative agreement a series of slides was prepared to document the transition of technology to aircraft systems. This slide summarized technologies incorporated into the Sikorsky S-76. A concentration in safety- related technologies may be noted.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

Bell Agusta BA-609 Civil Tiltrotor

- **NRTC/RITA collaboration has contributed significantly to the development of a new, civil tiltrotor aircraft that will revolutionize vertical-flight capabilities**

- **Technology enhancements for the BA-609:**
  - Composite structural design and manufacture: 1) Data for defining design allowables and (2) Many processing technologies
  - Special handling-qualities / control-law development …. for use with offshore, oil-platform operations
  - Precision, decelerating, steep-angle DGPS approaches: (1) Reduce community noise by up to 10 dB and (2) Enhance tiltrotor / heliport IMC operations
  - Cabin-noise prediction methodology to guide design
  - Advanced rotor-ice-protection system -- tunnel data and analytic methods

The BA 609 represents state-of-the-art design for a composite aircraft, within the civil transport design domain of primary interest to NASA. A host of new composite materials, fabrication processes, and component applications are incorporated into its design. The light weight metal parts fabricated with high speed machining technologies are also incorporated where the cost benefit is clear. Handling qualities have been analyzed as well, and are particularly important in view of V-22 experience. Noise reduction both inside the cabin and in the external community, coupled with ice protection systems will contribute to the wide utility of this aircraft.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

- **NRTC/RITA collaboration has contributed significantly to the development of the RAH-66, a helicopter that will revolutionize vertical-flight capability in the battlefield**

Boeing/Sikorsky RAH-66 Comanche

- **These technology enhancements are incorporated or being evaluated for use in the RAH-66 aircraft:**
  - ➔ Integrated Helicopter Design Tools (IHDT)
  - ➔ Composite design/manufacture:
    - Improved design criteria …. for defining material/design allowables
    - Advanced Resin Transfer Molding (RTM) … of various structural and non-structural components
    - Paste-adhesive joining process … for attaching stiffeners/frames to thin skins

The Boeing/SikorskyComanche design has leveraged significantly off the web-based design tools developed under the Integrated Helicopter Design Technology (IHDT) and follow on Technology for Rotorcraft Integrated Analysis and Design (TRIAD) efforts within RITA and the government. The aircraft uses a number of advanced composite materials and processes.

Technology Commercialization

Boeing/Sikorsky RAH-66 Comanche (Continued)

- Advanced Ice Protection System for engine inlet …. based on wind-tunnel test results at NASA Glenn
- Improved directional-control characteristics … based on fan-in-fin unsteady-aerodynamics research
- Fly-by-wire flight control system with tactile pilot cueing ….. from active, three-axis sidestick controller work
- Health and Usage Monitoring Systems (HUMS) …. an integral part of aircraft systems (… benefiting safety and cost)

Comanche specifications also demand extreme agility, requiring new technologies for flight control and man-machine interface. HUMS technology will provide critical flight safety information to the pilot and improve the long term affordability of the weapons system.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

- **NRTC/RITA collaboration has contributed significantly to engineering improvements in the V-22 tiltrotor aircraft**
- **These technology enhancements are incorporated or being evaluated for use in the MV-22 and/or CV-22 aircraft:**
  - ➔ Composites design/manufacture:
    - Predictive tool for thick composites (main rotor grip, yoke and blade spar)
    - Fiber waviness (“Marcelling”) accept/reject criteria (initial application: V-22 spindle)
    - Confirmation of skin damage limits (for repair)
    - High-temperature applications (engine door/work platform)
    - Advanced manufacturing concepts (structural beams for inner-side skin, frames, belly skin)
    - Resin transfer molding (various structural and non-structural components)

Bell Boeing V-22 Osprey

The V-22 program has significantly advanced the state-of-the-art in composite aircraft design. Technical challenges have been overcome which permit designers to capitalize on the use of composites for everything from very thick structures such as rotor hubs and drive shafts to very thin structures such as post-buckled aircraft skins. Other materials development successes include grid stiffened components capable of surviving high temperature environments, and resin transfer molded processes for low cost non-structural components.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

- Flow-field-analysis tool (Hybrid LES/RANS)…. correcting flow separation, tail buffet, and rotor/fuselage interactions
- High-speed titanium machining --- blade-fold mechanism (6 per aircraft)

Bell Boeing V-22 Osprey (Continued)

- Avionics tailoring ….. aided by "Interference Cancellation" report (to evaluate addition of third VHF/UHF radio in MV-22)
- Avionics open architecture guidelines -- require-ments for a new radar system for CV-22
- Composite airframe lightning protection… improved by new skin panel edge treatment and connector bonding process
- Tiltrotor-aircraft download-reduction concept (flight-validated… with structural/weight/cost analysis)
- Precision Pathway Terminal Guidance (PPTG) flight symbology for V/STOL aircraft

RITA technology has contributes to the solution of several other challenges for the V-22, including analysis tools to alleviate tail buffeting, avionics architecture and RFI standards, precision navigation capabilities, and aircraft skin treatments to mitigate the damage caused by lightning strike.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

- **NRTC/RITA collaboration has contributed significantly to engineering improvements in the H-60 series of aircraft**
  - **These technology enhancements are incorporated or being evaluated for use in H-60 aircraft:**
    - Modifications developed/integrated with Integrated Helicopter Design Tools (IHDT) web-based tools
    - Active vibration-reduction concepts
    - Damage-Tolerance technology …. for determining inspection intervals for UH-60 hub; beginning to integrate into new designs (UH-60M/X) and SH-60R/CH-60S
    - Advanced Rotor Ice Protection System (RIPS) …. icing tunnel test results used in H-60 Wide Chord Blade qualification
    - HUMS open-system interface specifications … U.S. Navy fleet implementation
    - High-speed machining of thin-walled structures

Sikorsky H-60 Series

Rotorcraft Transition Workshop – September 5, 2001 17

The Blackhawk and Seahawk upgrades have exercised the distributed design features of the IHDT and TRIAD tools developed by RITA. High-speed machining technology permits the use of large monolithic thin-wall ultralight components that improve reliability and reduce fabrication costs. Advances in the understand of damage tolerance in metal components subjected to the unique load spectrum encountered in rotorcraft primary load-path components, coupled with HUMS technology to monitor and record life usage, will permit the safer and more economical design and maintenance of these components during the fleet's extended service life. Specific sub-systems for vibration reduction and ice mitigation improve the safety and effectiveness of the H-60 aircraft.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

- **NRTC/RITA collaboration has contributed technologies that improve the aircraft weight/ performance, subsystems design and maintenance/ aircraft readiness**

Boeing AH-64 Apache

- Variable-speed, vapor-cycle technology … more efficient power use for avionics cooling
- Composites technology: adaptive cure and cure-control monitoring for new composite blades
- Damage-tolerance methodology/data for life prediction of components (i.e., safety and lower-cost maintenance)

The Apache utilizes RITA technology in it's new composite blades. A light-weight, high efficiency vapor cycle cooling system helps keep the pilot and avionics cool, and damage tolerance methodologies will improve the safety record for the aircraft and reduce fleet operating costs.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

NRTC/RITA collaboration has contributed new materials technologies and component designs to extend the life of these aircraft into the next decade

Bell H-1 Upgrades

➔ Composite structures technology for lower weight and cost:

- Melt-bond-joints
- Injection-molded components
- Grid-stiffened, high-temperature structures
- Resin Transfer Molded (RTM) components

Upgrades to the Cobra and Huey include RITA developed composite materials and processes that reduce weight and cost to manufacture.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

- **NRTC/RITA Collaboration has produced technology enhancements that are incorporated or being evaluated for use in the Sikorsky S-76 helicopter**
- **These technologies have a direct impact on the NASA OAT goals for noise reduction, and aircraft safety:**

Sikorsky S-76 Series

- ➔ New approach procedures ……. for HAI Fly Neighborly Guide/Program and S-76 Operators Conference/Newsletters
- ➔ Cabin tonal-noise-control technology .... demonstrated
- ➔ FAA RPTERPS criteria for precision, decelerating, steep-angle DGPS approaches ……. that reduce community noise levels and enhance helicopter/heliport IMC operations (2000 AHS Frederick L. Feinberg Award)
- ➔ Damage-tolerance technology ……. determines inspection intervals on S-76C+ engine
- ➔ Enhanced ground-proximity-warning system (EGPWS) for safety….. demonstrated system; provided draft FAA Advisory Circular for implementation (2001 AHS Howard Hughes Award)

Rotorcraft Transition Workshop – September 5, 2001 20

RITA has developed several flight operations enhancements for the S-76 which will alleviate community noise and reduce the number of accidents resulting from controlled flight into terrain. Interior noise reduction subsystems technology has significantly reduced drivetrain noise transmitted to the passenger compartment. Damage tolerance methodologies will also contribute to safe operation and reduced costs.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

Boeing CH-47 Chinook

- **NRTC/RITA collaboration has contributed new materials technologies and component designs to increase safety, quiet the ride, and extend the life of these aircraft into the next decade**
  - ➔ Resin transfer molding of primary structure (Improved Fuel-Isolation System *[IFIS]* beams)
  - ➔ HUMS open system-interface specifications, advanced-sensor technology, and cost/benefits model
  - ➔ Interior-noise prediction and reduction

The Chinook is another aircraft that is being utilized far beyond it's intended design life. RITA HUMS technology will monitor and manage the performance of aging airframe, drive-train, and power-plant components. Composite materials and noise reduction technologies have been applied to this aircraft also.

Technology Commercialization

Rotorcraft Program
National Rotorcraft Technology Center

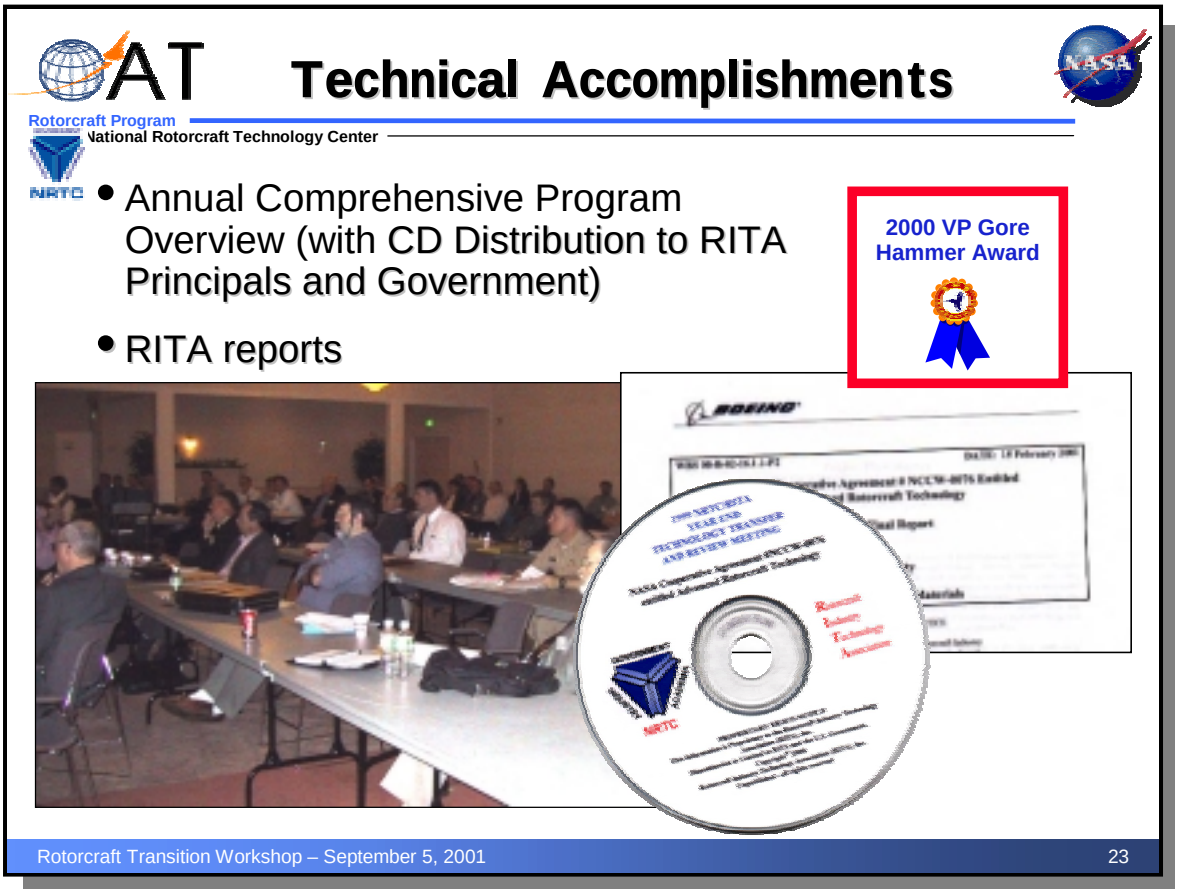
- **NRTC/RITA collaboration has produced technology enhancements for Bell 407, 412, and 427 aircraft:**
  - Composite-material structural design and manufacture:
    …….. data defining material-design allowables
    …….. numerous processing technologies
  - Improved resin-transfer molding (RTM) composites
  - Superplastic-forming of aluminum
  - High-speed machining of highly loaded, titanium parts

- **Composite-materials and metal-processing techniques help build safe aircraft**

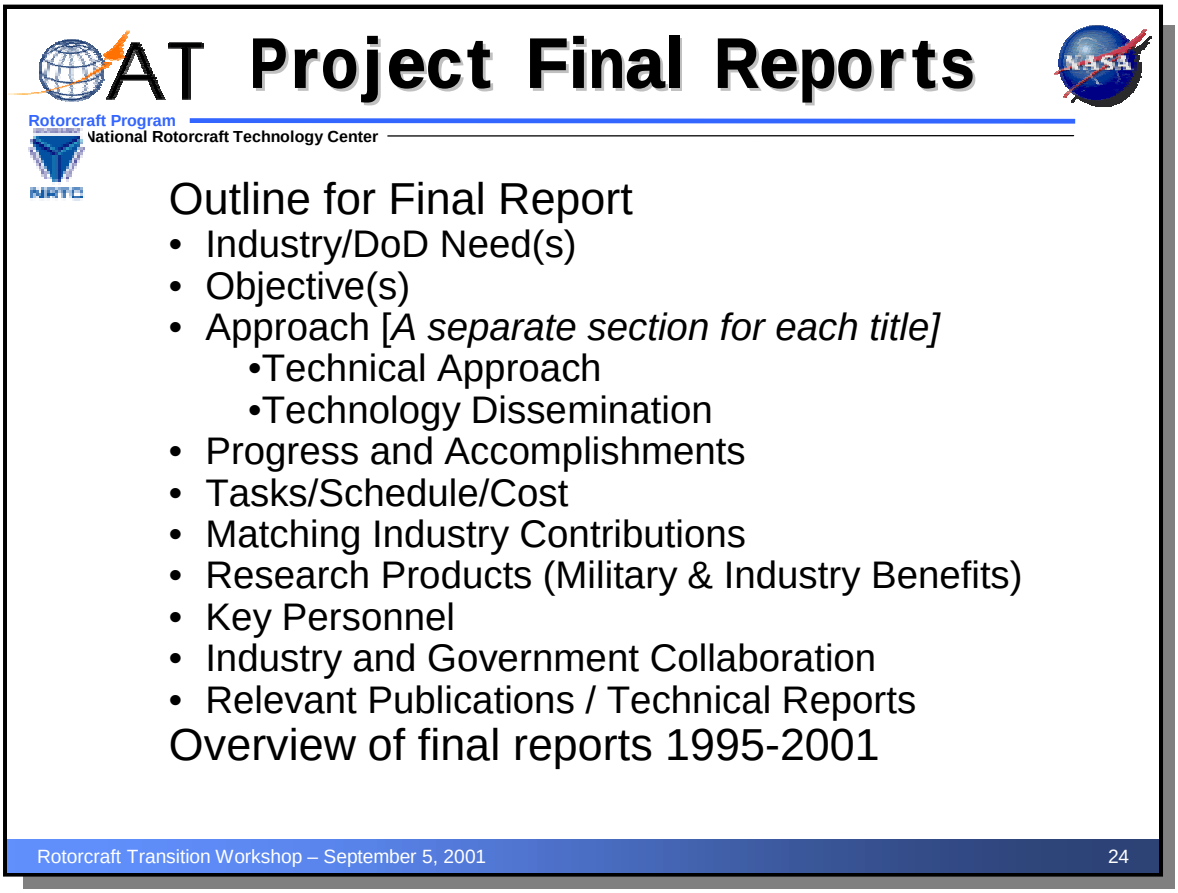
Bell 400 Series

Rotorcraft Transition Workshop – September 5, 2001 22

Bell commercial helicopters incorporate several RITA developed materials and fabrication process technologies.



The annual RITA Year End Review serves as the principal project level milestone in the NASA NRTC Project, with “technology transfer” , among all government and RITA participants as the stated objective. The RITA Technical Advisory Committee organizes and leads this meeting. Each RITA project is reviewed against it’s proposed objectives, budget, and schedule. Accomplishments and findings are presented and discussed, with emphasis on information that can be shared to good advantage among all interested RITA members. A CD of all the (RITA proprietary) presentation materials is produced each year and distributed to the RITA principal members and throughout the government. This series of CDs, (1997 through 2001) represents an important archive of the knowledge product of this NASA project.



The Funded Cooperative Agreement that defines the relationship between the NRTC government office and RITA provides for a series of reports to be delivered to the Government as part of the life cycle of each RITA project. In addition to periodic status reports which permit the government to monitor progress against the project objectives and provide guidance and problem solving assistance, a comprehensive final report is provided at the end of each (single or multi-year) RITA project series. Each final report reviews objectives, funding, and technical approach, identifies points of contact, documents findings, and references supporting reports and data. This series of RITA proprietary reports is available for distribution within the government and represents another important archive for the NASA NRTC project knowledge product.

Open Literature Pubs

- Bibliography provided with more than 80 citations
- RITA TAC screens all publications to ensure that proprietary material stays within RITA
- Most effective use of open literature publications relates to establishing standards